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(NASA-CR-171122) RESEARCH PRESSURE
INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN
ENGINE, MODIFICATION NO. 5 Monthly Progress
Report (Honeywell, Inc.) 31 p HC A03/MF A01

N84-31594

CSCL 14B G3/35 00960

Unclass

RESEARCH PRESSURE INSTRUMENTATION

FOR

NASA SPACE SHUTTLE MAIN ENGINE

NASA CONTRACT NO. NAS8-34769

MODIFICATION NO. 5

MONTHLY REPORT

GEORGE C. MARSHALL SPACE FLIGHT CENTER

MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

MAY 1984

Prepared By:

P.J. ANDERSON, PROGRAM MANAGER
P. NUSSBAUM, TECHNICAL DIRECTOR
G. GUSTAFSON, DEPUTY TECHNICAL DIRECTOR

HONEYWELL INC.
SOLID STATE ELECTRONICS DIVISION
12001 STATE HIGHWAY 55
PLYMOUTH, MN 55441



HONEYWELL INC.
SOLID STATE ELECTRONICS DIVISION
CONTRACT NO. NAS8-34769
MODIFICATION NO. 5

RESEARCH OF PRESSURE INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN ENGINE

Monthly R & D Progress Report May 1984 - Report No. 8

A. Technical Progress and Plans

- See attachment 'A'

B. Schedule

- See attachment 'B'

C. Status of Funds

	<u>LBM</u>
Total Baseline Plan	\$407,350
Total Funded	\$300,000
Cost Incurred to 6/03/84	\$242,000
Inception to Date Plan	\$217,600
Estimate at Completion	\$407,350

D. Estimated percent of physical completion: 59%

E. At the present time the comparison of the cumulative costs to the percent of physical completion does not reveal any significant variance requiring explanation.

ATTACHMENT 'A'

RESEARCH PRESSURE INSTRUMENTATION
FOR
NASA SPACE SHUTTLE MAIN ENGINE
HONEYWELL, INC.

1.0 Introduction and Objective

The first phase of this contract (Tasks A and B) resulted in a highly successful demonstration in April 1983 at the MSFC of Honeywell's breadboard feasibility model of a silicon Piezoresistive Pressure Transducer suitable for SSME applications.

The purpose of Modification No. 5 of this contract is to expand the scope of work (Task C) of this research study effort to develop pressure instrumentation for the SSME. The objective of this contract (Task C) is to direct Honeywell's Solid State Electronics Division's (SSED) extensive experience and expertise in solid state sensor technology to develop prototype pressure transducers which are targeted to meet the SSME performance design goals and to fabricate, test and deliver a total of 10 prototype units.

SSED's basic approach is to effectively utilize the many advantages of silicon piezoresistive strain sensing technology to achieve the objectives of advanced state-of-the-art pressure sensors in terms of reliability, accuracy and ease of manufacture. More specifically, integration of multiple functions on a single chip is the key attribute of this technology which will be exploited during this research study.

The objectives of this research study will be accomplished by completing the following major tasks:

1. Transducer Package Concept and Materials Study

Three transducer design concepts will be generated and analyzed for the SSME application and materials/processes will be defined for the research prototype transducer design.

2. Silicon Resistor Characterization at Cryogenic Temperatures

The temperature and stress properties of a matrix of ion implanted piezoresistors will be characterized over the temperature range of -320°F to +250°F.

3. Experimental Chip Mounting Characterization

The mechanical integrity of chip mounting concepts will be evaluated over temperature, pressure and vibration.

4. Frequency Response Optimization

This task is a paper study which will specify and analyze an acoustic environment for which transducer frequency response can be determined and optimized.

5. Prototype Transducer Design, Fabrication, and Test

This major task will use the results generated in Tasks 1 through 4 above to design and develop a research prototype pressure transducer for the SSME application and will culminate in the delivery of 10 transducers, 5 each for the ranges of 0 to 600 psia and 0 to 3500 psia. This task is subdivided into the following five areas:

- Feasibility Evaluation of Transducer Concept
- Prototype Transducer Design
- Prototype Transducer Fabrication and Test
- Prototype Qualification
- Prototype Delivery.

6. Reports

Honeywell will submit monthly progress reports during the period of the contract; a final report will be provided at the completion of the contract.

The format of this report will be to discuss the work performed for this reporting period and the plans for the next reporting period for each of the major tasks outlined above.

2.0 Work Performed and Plans

2.1 Transducer Package Concept and Materials Study.

This task was completed per plan during January 1984.

2.2 Silicon Resistor Characterization at Cryogenic Temperatures.

2.2.1 Work performed in May.

This task was completed during this reporting period.

Two cryogenic test runs have now been completed down to -425°F. There were three sensors per run. Both TE bonded and "floating" sensor chips were evaluated. An implant dose of 1.28 E15 has the desired TCR and temperature-pressure sensitivity characteristics and was selected for use in the fabrication of the Feasibility Sensor Chip. Attachment 'C' contains some examples of the sensor characteristics from the second cryogenic run.

2.2.2 Plans for June

No activity is planned for the next reporting period since this task was completed in May.

2.3 Experimental Chip Mounting Characterization

2.3.1 Work performed in May

Detailed and interface drawings were recieved from Deutsch Connector during this reporting period. This allowed the design of the Experimental Sensor (electrically nonfunctional) piece-part hardware to be completed.

The design and fabrication of vibration fixturing to accommodate testing up to 150g's was completed. The design of vibration fixturing to accommodate 4,000g's was started.

The decision was made during this reporting period to pursue the Au/Ge solder approach for assembling the Experimental Sensor devices that are electrically nonfunctional. Those sensors will be used to assess the mechanical integrity of our selected sensor design approach. (Re: Honeywell's April Monthly Report, Attachment 'D' (Alternate D)).

The solder creep experiment for the aforementioned approach was beyond the scope of the original plans for this task. This work was stopped based on cost considerations. The impact of solder creep, if it is significant, will be evaluated from the temperature/pressure testing of the Feasibility Sensor devices later on in this program.

The status of the piece-part build for the Experimental Sensor is as follows:

- Silicon Nitride Parts: Material on order (due early June)
- Stainless Steel Housing: Complete
- Stainless Steel Base: Complete
- Pyrex Cover Glass and Mounting Washer: Material Received and is being lapped and polished (estimate-to-complete is mid June)
- Au/Ge Performs: Complete
- INVAR mounting plate: Complete

An updated and more complete materials list was completed and forwarded to Mr. T. Marshal under separate cover. See Attachment 'D' for details.

2.3.2 Plans for June

The plans are as follows:

- Complete design and start the fabrication of these test fixtures:
 - Vibration testing (4,000g's).
 - High pressure testing.
 - High pressure leak checking.
- Receive these parts:
 - Silicon nitride subassemblies.
 - Lapped and polished pyrex washer.
 - Lapped and polished cover-window.
- Complete assembly of experimental sensors.
- Complete temperature, pressure and vibration testing.

2.4 Frequency Response Optimization

This task was completed per plan in February 1984.

2.5 Temperature Sensor Network Concept Study.

This task was deleted when the contract was negotiated.

2.6 Prototype Transducer Design, Fabrication and Test

2.6.1 Feasibility Evaluation of Transducer Concepts.

2.6.1.1 Define/Finalize Concept for Feasibility Transducer.

.1 Work performed in May

The design of the Feasibility Sensor and an internal design review were completed. Also the layout of this sensor chip was started and completed, including incorporation of changes recommended from the design review. Attachment 'E' is a summary of the sensor design and the layouts as it will be submitted to the mask shop.

Two sources for silicon washer material were identified. These sources are:

- SS&ED Inventory
- Monsanto

The thickness of the wafers will be in the 22-24 mils range. The SSED material will be used at the primary source and Monsanto as a back-up source of supply.

.2 Plans for June

The plans are as follows:

- Complete mask fabrication for Feasibility Sensor.
- Start wafer processing.

2.6.1.2 "Prototype" Transducer Design

.1 Work performed in May

This task was closed per plan as reported in our April Monthly Report. Recall, the activity being addressed recently was Frequency Response design considerations. The work performed was a logical extension of the "Frequency Response Optimization" task, (Re: Section 2.4). Rather than stop and restart this activity as part of the "Prototype Transducer Design", we elected to keep the momentum going and complete it as reported last month.

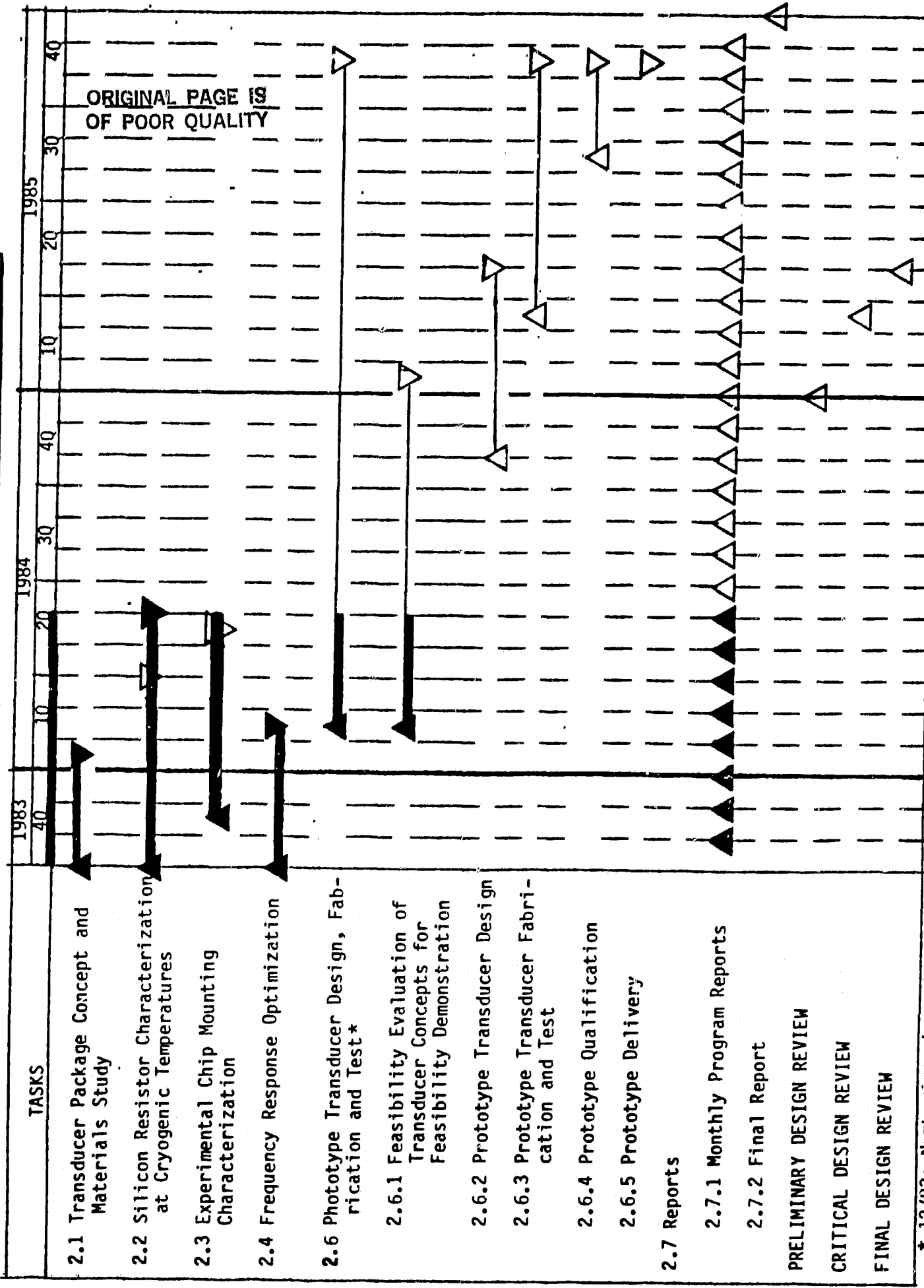
.2 Plans for June

No activity is planned for this reporting period. This task is scheduled to be reopened in 11/84.

3.0 Schedule -- See Attachment 'B'.

The "Experimental chip Mounting" task was not completed in May as planned. The major elements leading to this delay were the re-evaluation of the assembly approach and longer than planned delivery of the pyrex and silicon nitride materials. The plan is to complete this task in June; however, that is contingent upon the timely delivery of the polished pyrex glass and silicon nitride materials. It is possible that completion of this task will slip to July, 1984. This delay is not expected to have an adverse impact on the completion of the Feasibility Sensor task. (Re: Section 2.6.1)

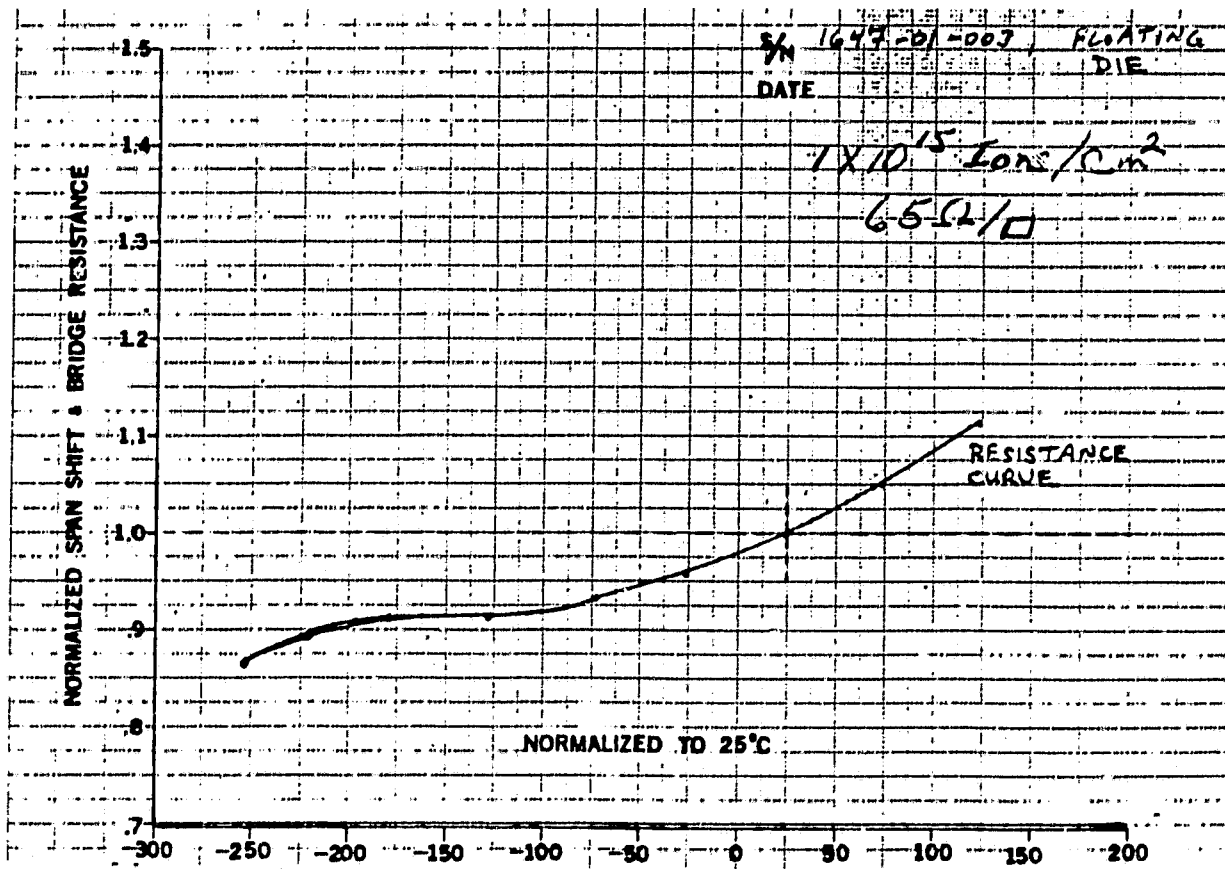
RESEARCH PRESSURE INSTRUMENTATION FOR NASA SPACE SHUTTLE MAIN ENGINE
SCHEDULE



* 12/83: Numbering changed to retain numbering in original proposal. Task 2.5 was deleted during contract negotiations.

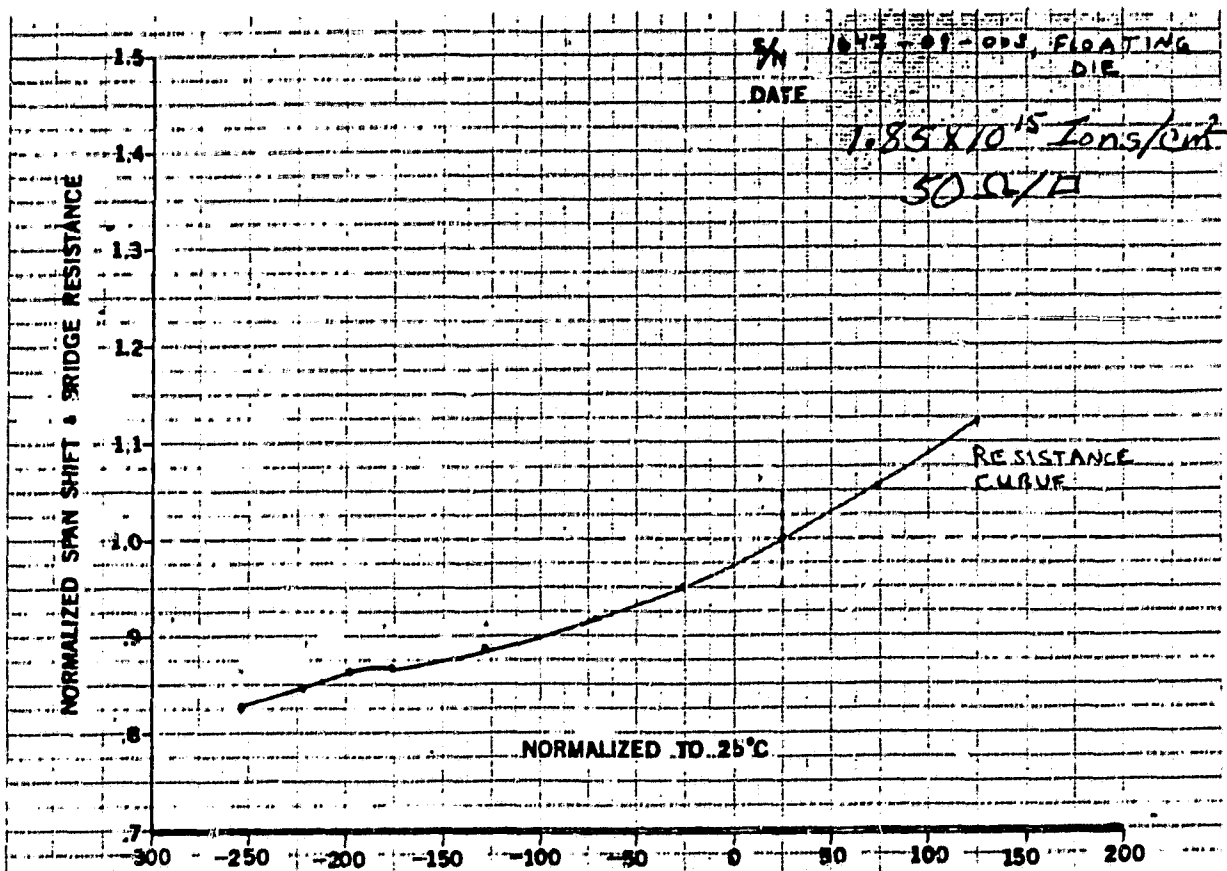
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ATTACHMENT "C"
NASA CRYOGENIC TESTING



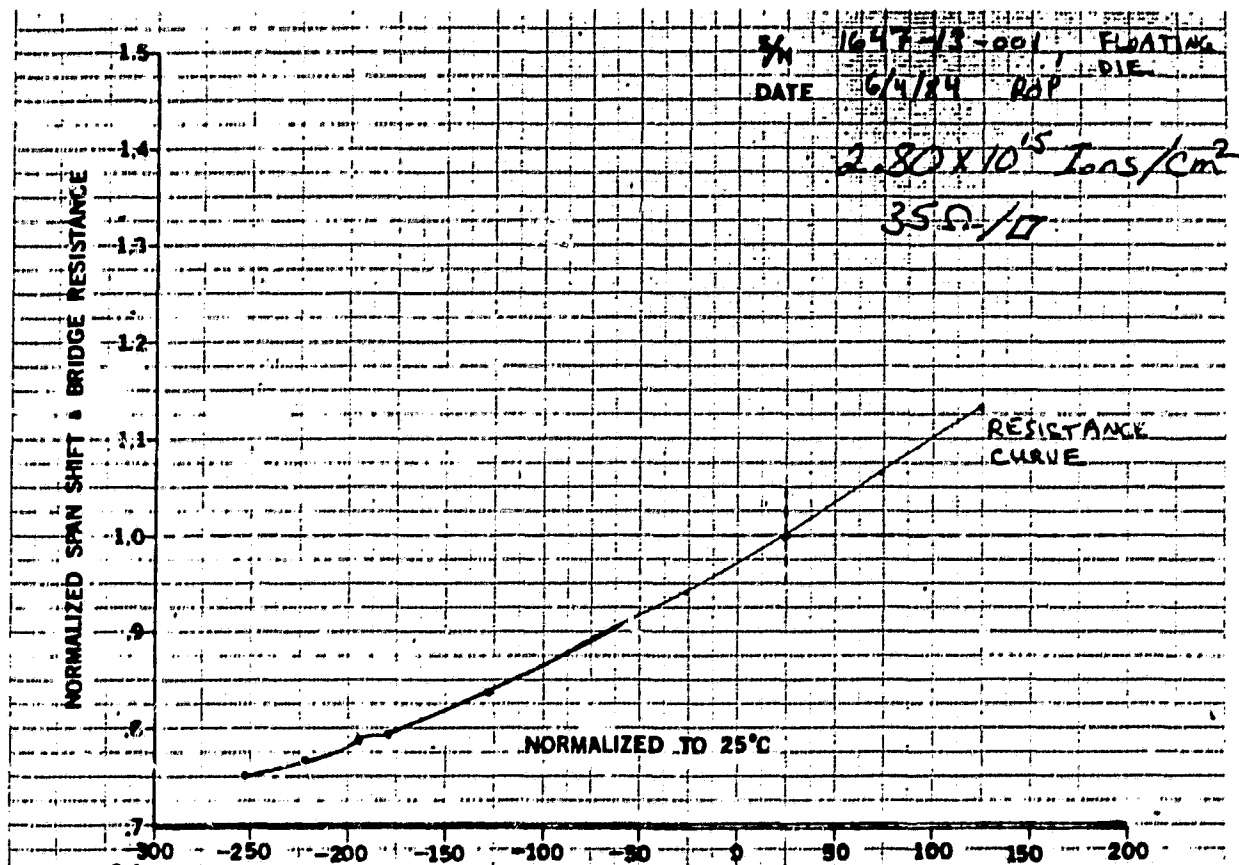
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ATTACHMENT "C"
NASA CRYOGENIC TESTING



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ATTACHMENT "C"
NASA CRYOGENIC TESTING



Honeywell

May 24, 1984

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Mr. Thomas Marshall
NASA
Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

RE: 1. NASA Contract No. NAS8-34769
2. Six Month Review At NASA/MSPC, 4/12/84
3. SSSED's Monthly Report for January, 1984, Attachment 'E', 2/9/84
4. My letter of 3/16/84 (Materials Testing and Evaluation)

Dear Tom:

Enclosed is a more comprehensive materials list which we are planning to use in the fabrication of our deliverable pressure transducers. (Reference 1) This list was prepared in response to your 12, April 1984 request for same. (Reference 2) Please review this list and provide us with your comments and questions as soon as possible. This list is an updated version of the one presented at our Six Month Review (Reference 2) and which was also included in our January Monthly Report. (Reference 3)

At our Six Month Review, you indicated that you were expecting, in the following week, to receive a reply from your Materials Lab regarding the support you can provide in the area of materials testing and evaluation of some materials for which we are either lacking data and/or are not on the approved list of NASA materials. (Reference 4) My records indicate we have not yet received a response from you on this subject.*

I am requesting that you review the review materials list and respond as soon as possible with your comments. Also, please include your response to our request for materials testing and evaluation support. (Reference 4)*

We look forward to hearing from you soon.

Sincerely,


J. Anderson
Program Manager

cc: P. Nussbaum	MN14-3B35	J. Onffroy	MN14-3B35
R. McMullen	MN14-3B35	D. Street	MN14-4C37
D. Wamstad	MN14-3B35	J. Shea	MN14-3B20

* Response Received 6/4/84

Honeywell

Interoffice Correspondence

Date: May 22, 1984

Subject: PROPOSED MATERIAL LIST FOR THE NASA PRESSURE TRANSDUCER

To: - P. Anderson MN14-3B25

cc: J. Onffroy MN14-3B35
J. Shea MN14-3B20From: D. Wamstad
Organization: SSER
HED: MN14
MS: 3B35
Telephone: 541-2091

The attached list of materials are proposed for the construction of the NASA Pressure Transducer. The list of material shows the location of materials as referenced by item number in Figures 1 and 2, and also provides the material interface temperature, pressure and pressure media which the material will be exposed to.

Would you submit this to NASA for their recommendations as to the suitability of the material.

D. Wamstad

DW/1w

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SSME PRESSURE SENSOR PACKAGE

NASA MATL. CODE	MATERIAL	INTERFACE		PRESSURE MEDIA	PART DESCRIPTION	ITEM NO.
		MIN. TEMP.	MAX. PRESS.			
Not Available	Silicon	-423°F	20K psi	He, H, N&O	Silicon Sensor Chip	1
Not Available	Silicon Nitride - Hot Press.	-423°F	<20K psi	He, H, N&O	Sensor Mount	2
Not Available	Silicon Nitride - Hot Press.	>-423°F	<20K psi	He (2.0 psia)	Elect. Terminal Board	3
Not Available	Gold (88%)/Germanium (12%)	>-423°F	<20K psi	No Specific Media	Solder	4
Not Available	Sputtered: Ti (1000°A)/Pt (9000°A) or Ti/Ni/Au	>-423°F	<20K psi	No Specific Media	Metalization	4
Not Available	Pyrex (Spec 7740 Corning)	>-423°F	~13 psia	He (2.0 psia)	Cover Glass	5
10338	PB (97.5%)/Sn(1%)/Ag(1.5%)	>-423°F	~13 psia	He (2.0 psia)	Solder	6
Not Available	Sputtered: Ti (1000°A)/Pt (9000°A) or Ti/Ni/Au	>-423°F	~13 psia	He (2.0 psia)	Metalization	6
Not Available	Pyrex (Spec 7740 Corning)	-423°F	20K psi	He, H, N&O	Pyrex Washer	7
Not Available	Sputtered: Ti (1000°A)/Pt (9000°A) or Ti/Ni/Au	-423°F	20K psi	He, H, N&O	Solder	8
10354	Copper Wire	>423°F	~15 psi	No Specific Media	Electrical Connectors	9
	Gold Wire .002" Dia.	>423°F	2.0 psia	He (2.0 psia)	Electrical Interconnects	10
*NOTE: For Item No. Designation See Figure 1						

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SSME PRESSURE SENSOR PACKAGE

NASA MATL. CODE	MATERIAL	INTERFACE		PRESSURE MEDIA	PART DESCRIPTION	ITEM NO.
		MIN. TEMP.	MAX. PRESS.			
10314	Invar - Alloy 36	> -423°F	~ 15 psia	No Specific Media	Interface Plate	11
10233	304L Stainless Steel	-423°F	20K psi	He, H, N&O	Housing	12
10233	304L Stainless Steel	-423°F	20K psi	He, H, N&O	Base	13
10139	Inconec X-750 Work Hardened	-423°F	20K psi	He, H, N&O	Metal C-Ring	14
Not Available	Deutsch Connector	> -423°F	20K psi	He, H, N&O	Res 1231-E-1005N	15

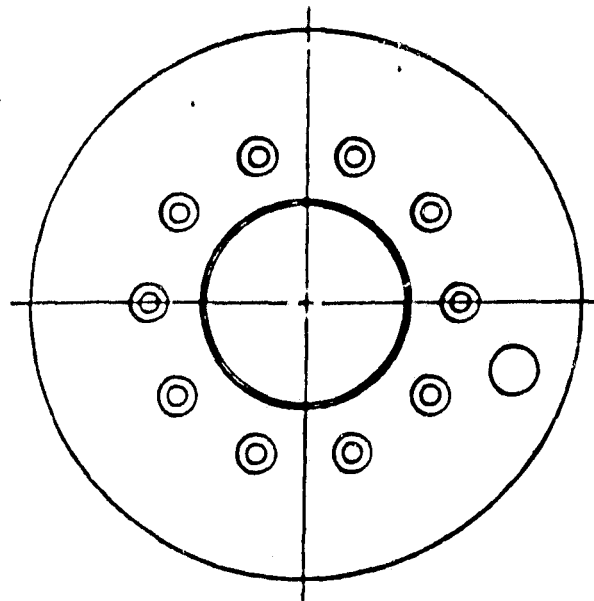
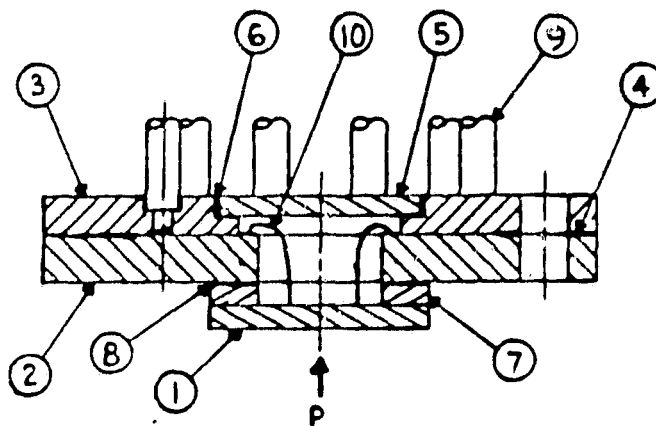
*NOTE: For Item No. Designation See Figure 2

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NASA PRESSURE TRANSDUCER PROGRAM

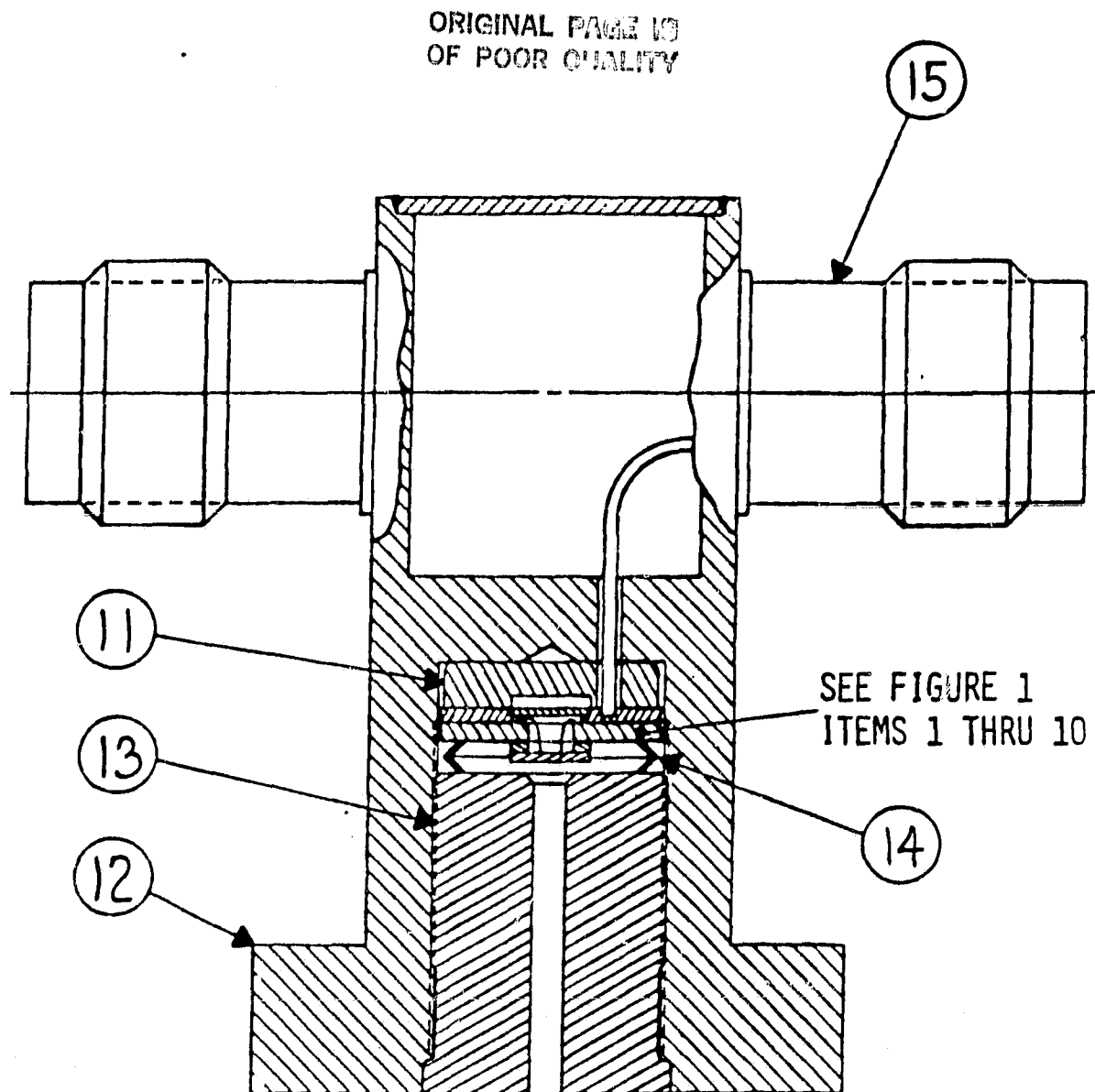
FIGURE 1: SSME PRESSURE SENSOR MOUNTING - SILICON TO SILICON NITRIDE MATCHED COMPRESSION SEALS

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- 10 GOLD WIRE LEADS
- 9 COPPER WIRE - TO PROVIDE ELECTRICAL CONNECTION BETWEEN SENSOR AND EXTERNAL CONNECTION.
- 8 SOLDER BOND
- 7 PYREX WASHER - TO PROVIDE SENSOR MOUNT AND SENSOR DIAPHRAGM.
- 6 SOLDER BOND - TO PROVIDE HERMETIC SEAL AND VACUUM REFERENCE.
- 5 COVER GLASS - TO ALLOW LASER TRIMMING OF THE SILICON SENSOR CHIP - COMPENSATING NETWORK AND PROVIDE A HERMETIC SEAL BETWEEN THE COVER.
- 4 SOLDER BOND - TO PROVIDE HERMETIC SEAL BETWEEN THE TWO (2) SILICON NITRIDE PARTS.
- 3 SILICON NITRIDE - TO PROVIDE HERMETICALLY SEALED ELECTRICAL CONDUCTOR PADS WITH ELECTRICAL ISOLATION AREA
- 2 SILICON NITRIDE - TO PROVIDE HERMETICALLY SEALED ELECTRICAL CONDUCTOR PADS FROM SILICON SENSOR CHIP TO LEAD WIRINGS.
- 1 SILICON SENSOR CHIP - BONDING AREA ON CIRCUIT SIDE.

NASA PRESSURE TRANSDUCER PROGRAM

FIGURE 2: SSME PRESSURE SENSOR PACKAGE - SILICON TO SILICON
NITRIDE MATCHED COMPRESSION SEALS - INVAR INSERT
WITH V-RING



- 15 ELECTRICAL CONNECTOR RES 1231-E-1005N
- 14 METAL V-RING
- 13 STAINLESS STEEL BASE
- 12 STAINLESS STEEL HOUSING
- 11 INVAR INTERFACE PLATE

ATTACHMENT "D" CONT.D.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION ROUTING SLIP		
MAIL CODE	NAME	Action
	P. ANDERSON	Approval
		Call Me
		Concurrence
		File
CC	J. ONY	Information <input checked="" type="checkbox"/>
	P. NUSSBAUM	Investigate and Advise
		Note and Forward
	D. WAMSTAD	Note and Return
		Per Request
	J. SHEA	Per Telephone Conversation
		Recommendation
	R. McMULLIN	See Me
		Signature
	J. STAR	Circulate and Destroy
	G. GUSTAFSON	
<p>ATTACHED IS RESPONSE RECEIVED FROM MATERIALS LABORATORY Re: DATA FOR MATERIALS USED IN PRESSURE SENSOR. IT APPEARS WE WILL HAVE TO ARRANGE FOR O₂ TESTING</p> <p>Re'd 6/4/84 PIP</p>		
NAME		TEL. NO. (or code) & EXT.
Tom Marshall		453-4626
CODE (or other designation)		DATE
EB 22		5-17-84

National Aeronautics and
Space Administration

ATTACHMENT "D" CONT'D.

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35812

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Rec'd
6/4/84
PJA

Reply to Attn of EH02 (84-193)

May 8, 1984

TO: EB21/Mr. Garrett

FROM: EH01/Mr. Schwinghamer

SUBJECT: Materials Testing SSME Technology Program Pressure
Transducer

Reference is made to your memorandum EB22(84-62). Honeywell requested the following information:

a. 304-CRES: Reaction data in hydrogen, oxygen, nitrogen and helium area range of -423°F to +200°F. Pressure limit of 20,000 psi, operating pressure of 9500 psi.

b. Silicon Nitride and INVAR: Above data plus thermal expansion, thermal conductivity, tensile strength and yield strength for temperature range of -423°F to +200°F.

Enclosure 1 contains data currently available in this Laboratory. There is no reacting problem with hydrogen, nitrogen and helium for the above materials. High pressure oxygen tests currently are limited to 10,000 psi. Please feel free to contact Mr. Riehl, EH31, directly regarding testing in oxygen.


R. J. Schwinghamer
Director
Materials & Processes Laboratory

cc:
EH02/Mr. Key
EH31/Mr. Riehl

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RELATIVE RESISTANCE TO HYDROGEN @ ROOM TEMPERATURE

DATA DERIVED FROM TEST ON NOTCHED ROUND BARS

304 RELATIVE PERFORMANCE

MAT'L	NOTCH CONC. FACTOR 'Kt	GAS PRESSURE (KSI)	RELATIVE NOTCH RATIO ENVIR: HYDROGEN/HELIUM
304	8	10	.87
316	8	10	1.00
321	8	5	.87
347	8	5	.91

316 CRES IS BETTER PERFORMER THAN 304!!!

THE LOW CARBON FORM "L" WILL PROVIDE RELATIVELY NO CHANGE FROM THE STANDARD CARBON VERSIONS OF 304 & 316.

(ALTHOUGH NOT IN CONTACT WITH HYDROGEN IN THE APPLICATION THE FOLLOWING IS PROVIDED FOR INFORMATION)

DATA ON INVAR WAS NOT AVAILABLE HOWEVER THE RANGE OF PERFORMANCE CAN BE ESTABLISHED FROM FOLLOWING DATA SINCE INVAR IS ESSENTIALLY 36% NICKEL WITH THE REMAINDER IRON.

INVAR RELATIVE PERFORMANCE

MAT'L	NOTCH CONC. FACTOR 'Kt	GAS PRESSURE (KSI)	RELATIVE NOTCH RATIO ENVIR: HYDROGEN/HELIUM
ARMCO IRON	8	10	.86
NICKEL 270 (ESSENTIALLY ALL NICKEL)	8	10	.70

INVAR EXPECTED TO BE BETWEEN THE GIVEN VALUES AND NO WORSE THAN .70 OR BETTER THAN .86.

2. Reheat to 600 F (315 C), hold 1 hour per inch (25 mm) of thickness, air cool.
3. Reheat to 205 F (96 C), hold 48 hours, air cool.

Mechanical Properties**Tensile Properties and Hardness**

Typical room temperature mechanical properties of annealed and cold worked 36 per cent nickel-iron alloy are shown in Table II.¹ The effect of temperature on the tensile properties of plate and forged bars in the annealed condition are shown in Figures 1 and 2.

36 per cent nickel-iron alloy is not notch-sensitive: the ratio of notched tensile strength to unnotched tensile strength is on the order of 1.10 at room temperature as well as at -320 F (-196 C).¹

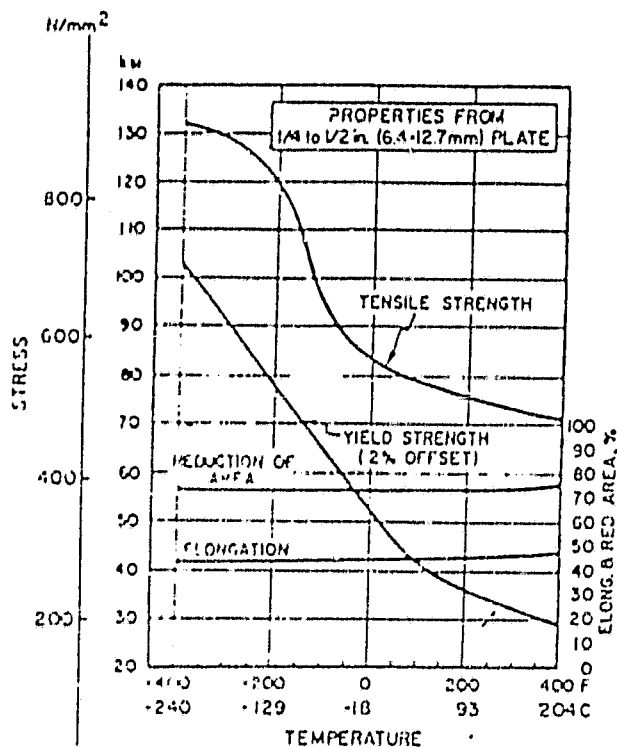


Figure 1. Effect of temperature on the typical tensile properties of annealed 36% Ni-Fe alloy.

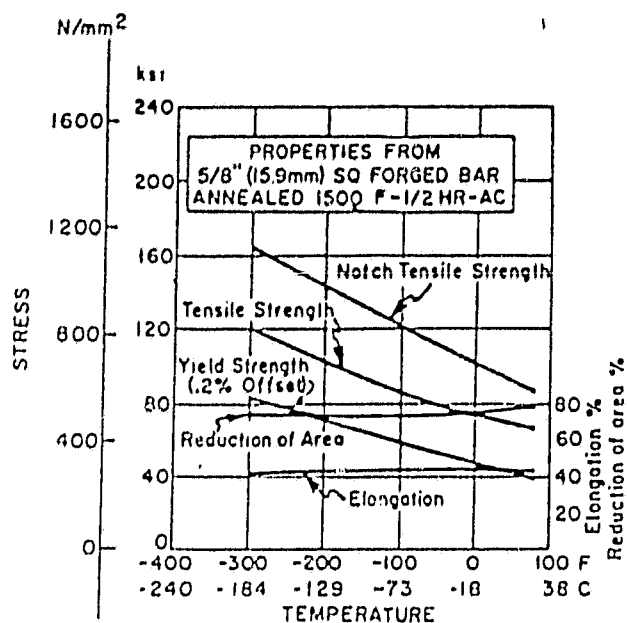


Figure 2. Effect of temperature on the tensile properties of forged 36% Ni-Fe alloy in the annealed condition.

TABLE II

Typical Mechanical Properties of 36 Per Cent Nickel-Iron Alloy

	Annealed	Cold Worked 15%	Cold Worked 25%	Cold Worked 30%
Tensile Strength, psi	71,400	93,000	100,000	106,000
N/mm²	(492)	(641)	(690)	(731)
Yield Strength (0.2% Offset), psi	40,000	65,000	89,500	95,000
N/mm²	(276)	(448)	(617)	(655)
Elongation (2 in. or 50 mm, %)	41	14	9	8
Reduction of Area, %	72	64	62	59
Brinell Hardness	131	187	207	217

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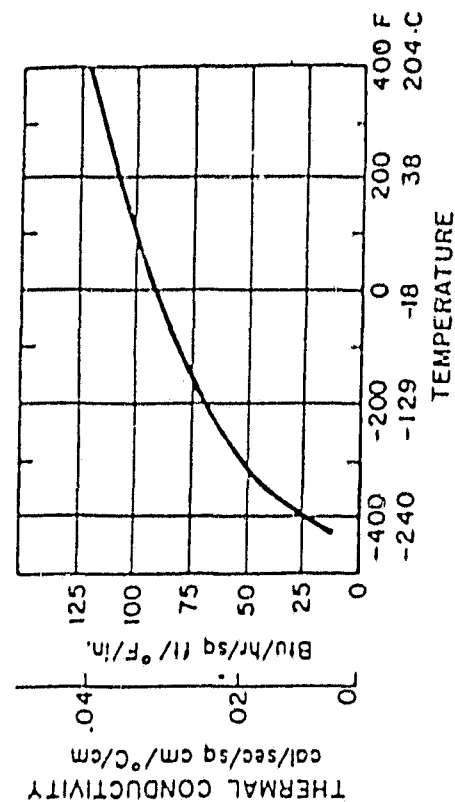


Figure 8. The effect of temperature on the Thermal Conductivity of 36% Ni-Fe alloy.

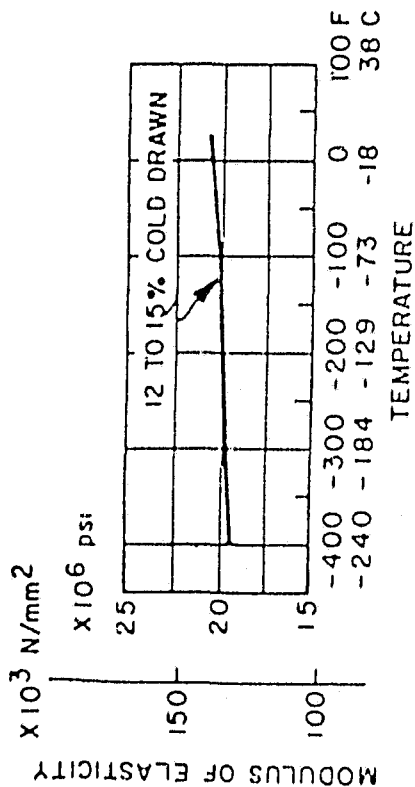


Figure 6. Effect of temperature on the Modulus of Elasticity of 36% Ni-Fe alloy.

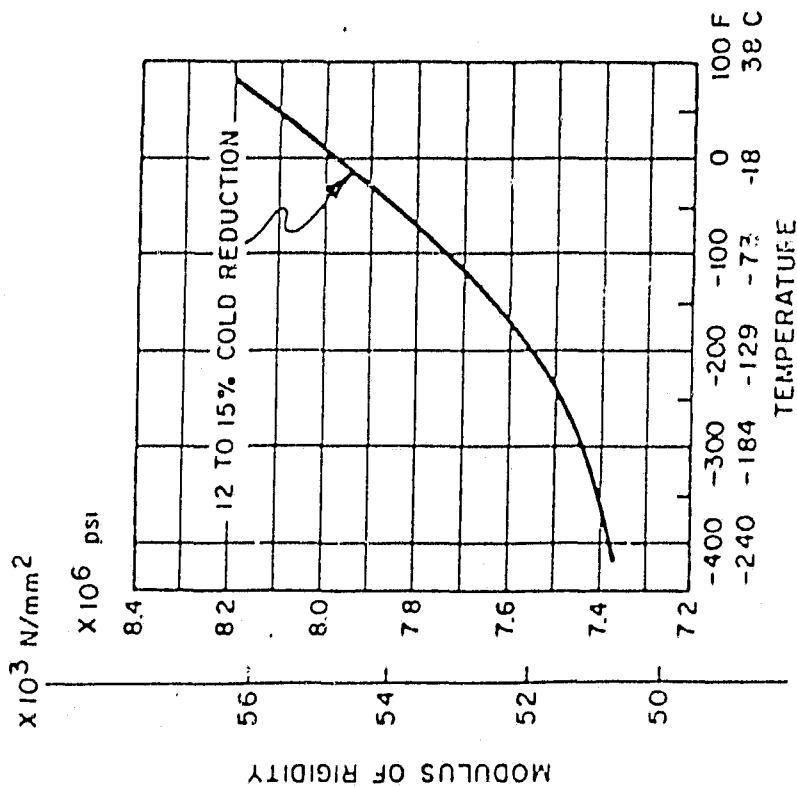


Figure 7. Effect of temperature on the Modulus of Rigidity of 36% Ni-Fe alloy.

TABLE VI

Thermal Expansion Data
on 36 Per Cent Nickel-Iron Alloy

Temperature Range F	Temperature Range C	Mean Coefficient of Linear Expansion per °F	Mean Coefficient of Linear Expansion per °C
-400 to 0	-240 to -18	1.20×10^{-4}	2.16×10^{-4}
-200 to 0	-129 to -18	1.10×10^{-4}	1.98×10^{-4}
0 to 200	-18 to 93	0.70×10^{-4}	1.26×10^{-4}
200 to 400	93 to 204	1.50×10^{-4}	2.70×10^{-4}
400 to 600	204 to 316	6.40×10^{-4}	11.52×10^{-4}

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EXPERIMENTAL SENSOR DESIGN

OBJECTIVE: Design and fabricate an experimental pressure sensor for use in the evaluation of the influence of the packaging concept on silicon piezoresistive pressure sensors over temperature, pressure, and vibration.

SCOPE: - Design and layout of an experimental sensor chip.

- Mask fabrication.
- Wafer processing.

APPROACH: - Minimize deviations from Honeywell's established silicon piezoresistive pressure sensor technology.

- Ion implanted, buried piezoresistors. Implant dose modified to enhance temperature compensation over extended temperature range (-320°F (77K) to 250°F (394K))
- Silicon slab or etched silicon cavity diaphragm
- TE chip bonding techniques
- Design to provide data for prototype sensor design
 - On chip metal inter-connects.
 - Wire bond interface to sensor chip.
 - Bridge resistance $\sim 500\ \Omega$

EXPECTED RESULTS: Experimental data base for use in determining the feasibility of the sensor packaging concept and for directing the prototype sensor design.

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REQUIREMENTS: Transducer Input and Output Resistance : 1350Ω to 2500Ω . Honeywell temperature compensation concept requires bridge resistance of $\sim 500\Omega$.

Sensitivity: 3 mv per volt of transducer bias.

S_B mv per volt of bridge bias.

$$S_B = (3) \times (\text{TRANSDUCER INPUT RESISTANCE}) / (\text{BRIDGE RESISTANCE})$$

Zero Pressure Output: < 0.03 mv per volt of transducer bias @ 75°F

$V_o(0)$ mv per volt of bridge bias

$$V_o(0) = S_B / 100$$

$$|R_R - R_T| < V_o(0) \times (R_R + R_T)$$

Burst Pressure: 3 times full scale or 20,000 psi, whichever is smaller.

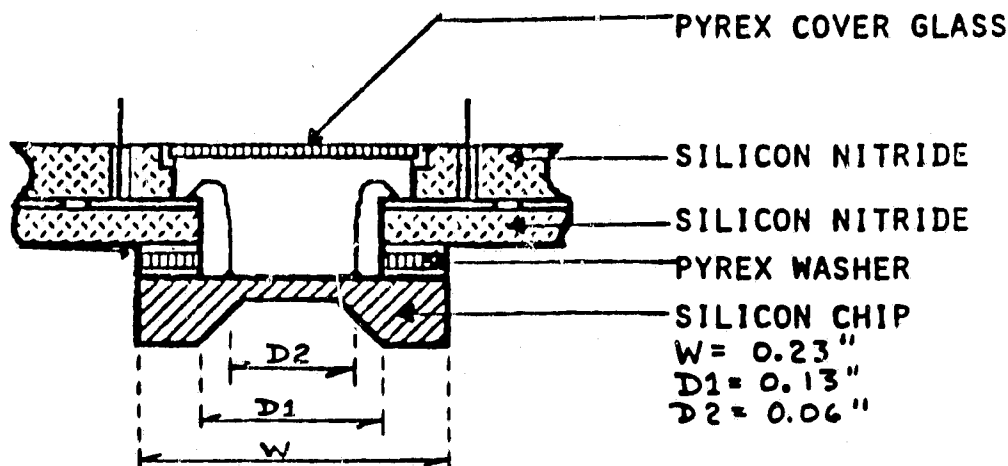
PACKAGE IMPOSED REQUIREMENTS:

- Unique packaging configuration
- Wire bond pads must be within $R2 = 0.5(D2) = 30$ mils
- Tolerance on D1

± 3 mils on pyrex washer ID

± 3 mils on packaging alignment

Maximum radial location of implant ≤ 60 mil



ORIGINAL PAGE 11
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POSSIBLE SENSOR CONFIGURATIONS

- Slab
 - 35 mil thick for 10,000 psi sensor
 - Diaphragm defined by ID of pyrex ring
 - Piezoresistors near inner edge of pyrex ring for maximum sensitivity
- Etched Diaphragm
 - 100 mil thick for 10,000 psi sensor
 - 40 mil diameter diaphragm
 - 15 mil thick diaphragm
 - Two piezoresistor locations for maximum sensitivity
 - Near edge of etched diaphragm
 - Near inner edge of pyrex ring

SELECTED SENSOR CONFIGURATION

- Slab Configuration
 - Sensors available sooner
 - Costs less
 - CONTRACT DOES NOT REQUIRE 20,000 PSI BURST PRESSURE DEMONSTRATION
- Silicon Wafers: Use maximum thickness that is
 - compatible with standard processing and fixturing at SSPC ($t < 25$ mils)
 - considered standard by silicon wafer suppliers ($t \neq 15$ mil is not standard and a special order)
- Available Starting Material: 15 mil silicon with a 7 to 9 mil thick epi

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DESIGN DETAILS

- Piezoresistors

- $35 \Omega / \square$
- Width = 13 microns
- Length adjusted to yield a bridge resistance of 647.6Ω
- $L = 160$ microns
- $(L/W)(35) = 430.8 \Omega / \text{piezoresistor}$

- Leadouts

- $35 \Omega / \square$
- Tangential Resistor Leadout
 - $R = (3.098)(35) = 108.4 \Omega$
 - $2R = 216.8 \Omega$
- Radial Resistor Leadouts
 - $R1 = (3.383)(35) = 118.4 \Omega$
 - $R2 = (2.814)(35) = 98.5 \Omega$
 - $R1 + R2 = 216.9 \Omega$

- Bridge Resistance: 647.6Ω

- Zero Pressure Output

$$|R_R - R_T| < 0.00012 (R_R + R_T)$$

$$R_R = 647.7 \Omega$$

$$R_T = 647.6 \Omega$$

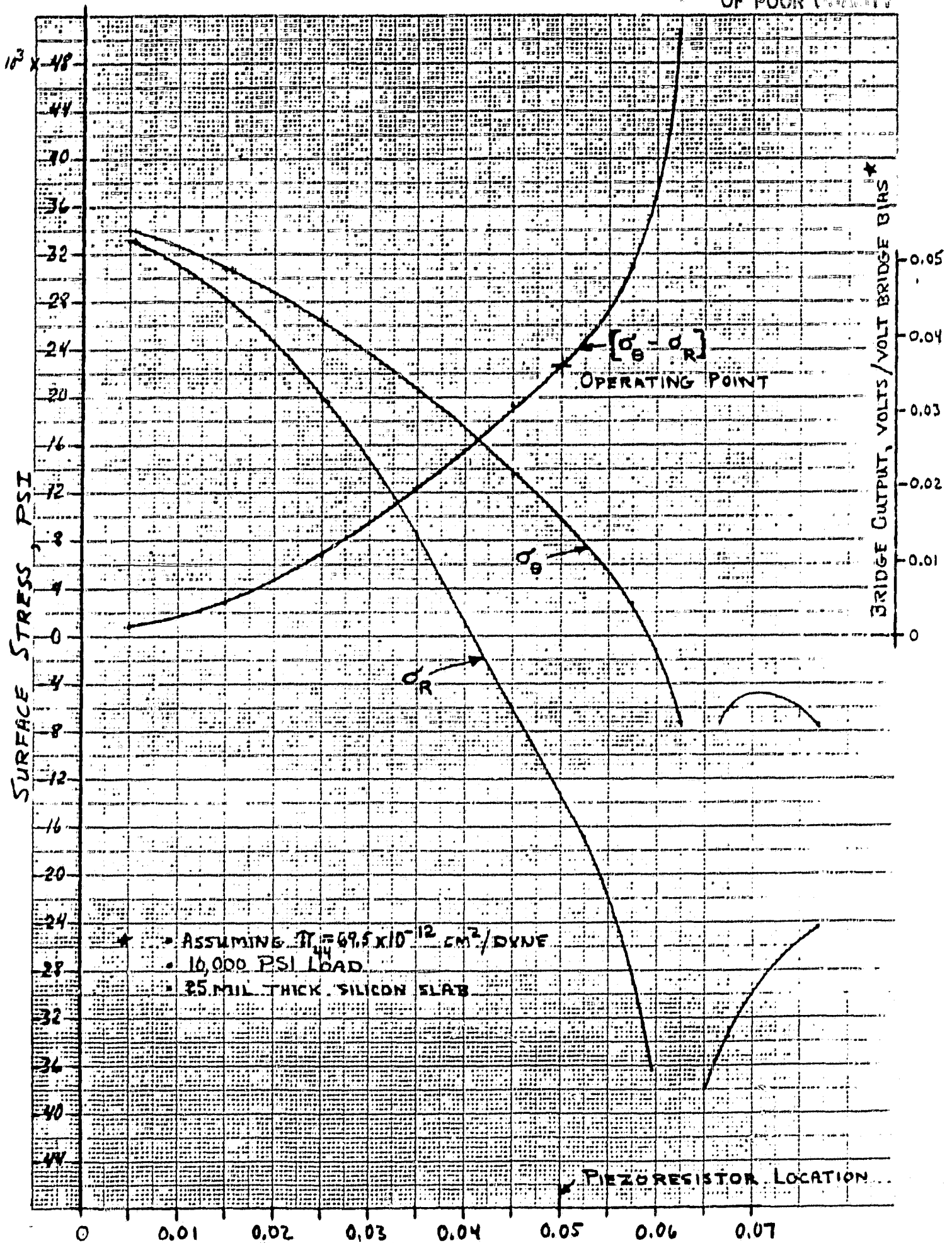
$$|R_R - R_T| = 0.1 \Omega < 0.00012 (R_R + R_T) = 0.15 \Omega$$

- Burst Pressure = 14,000 psi

- MAXIMUM OPERATING PRESSURE ≤ 4670 PSI

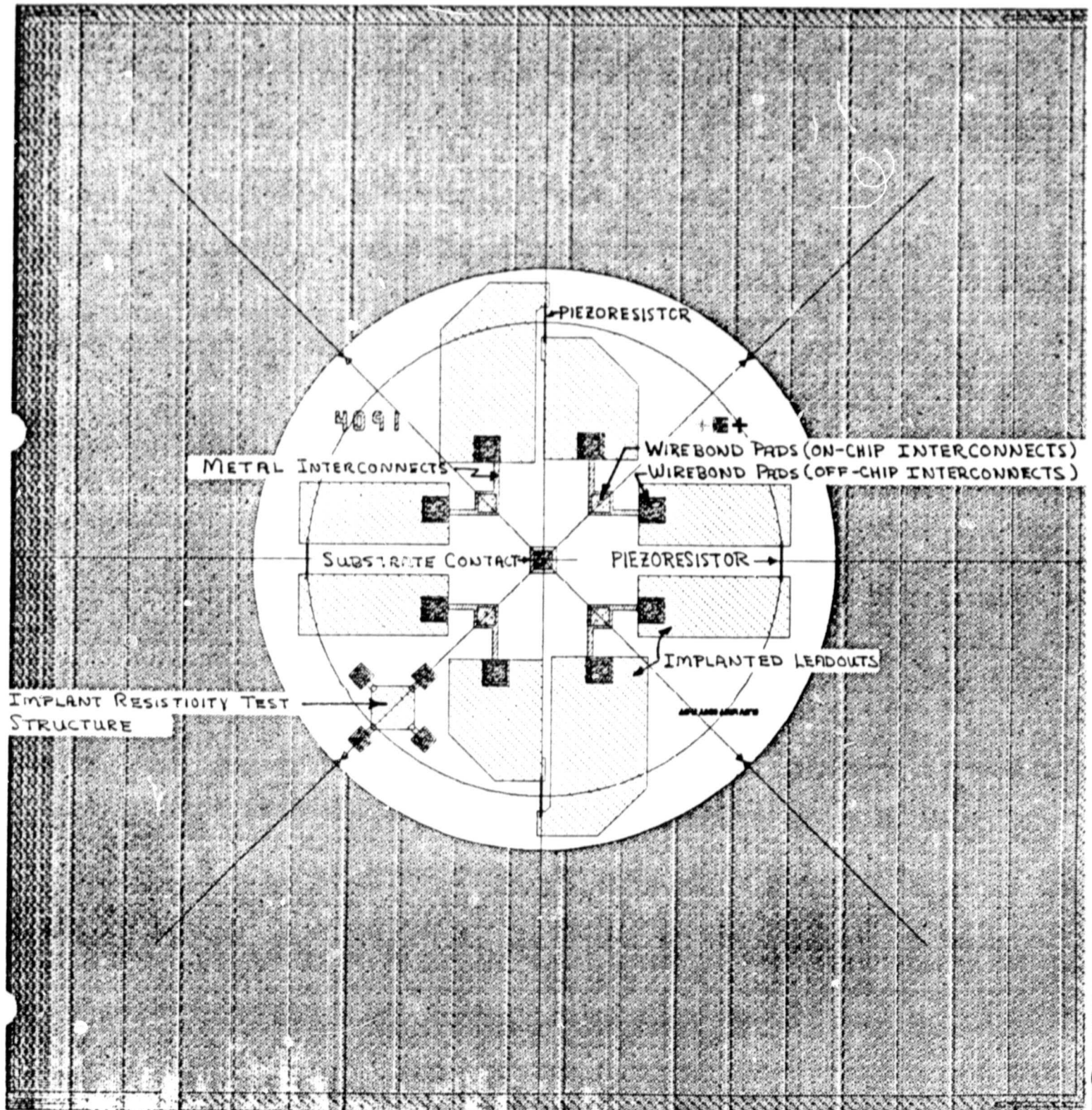
- CALCULATED SENSITIVITY = 17 mV/VOLT OF BRIDGE BIAS

$$\text{REQUIRED SENSITIVITY} = 12 (= S_B) \text{ mV/VOLT OF BRIDGE BIAS}$$



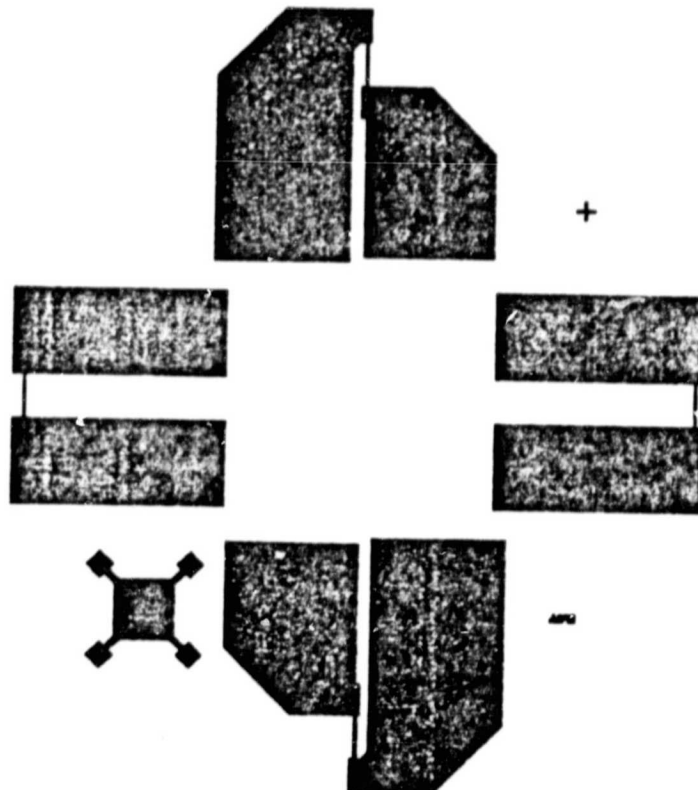
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COMPOSITE LAYER PLOT



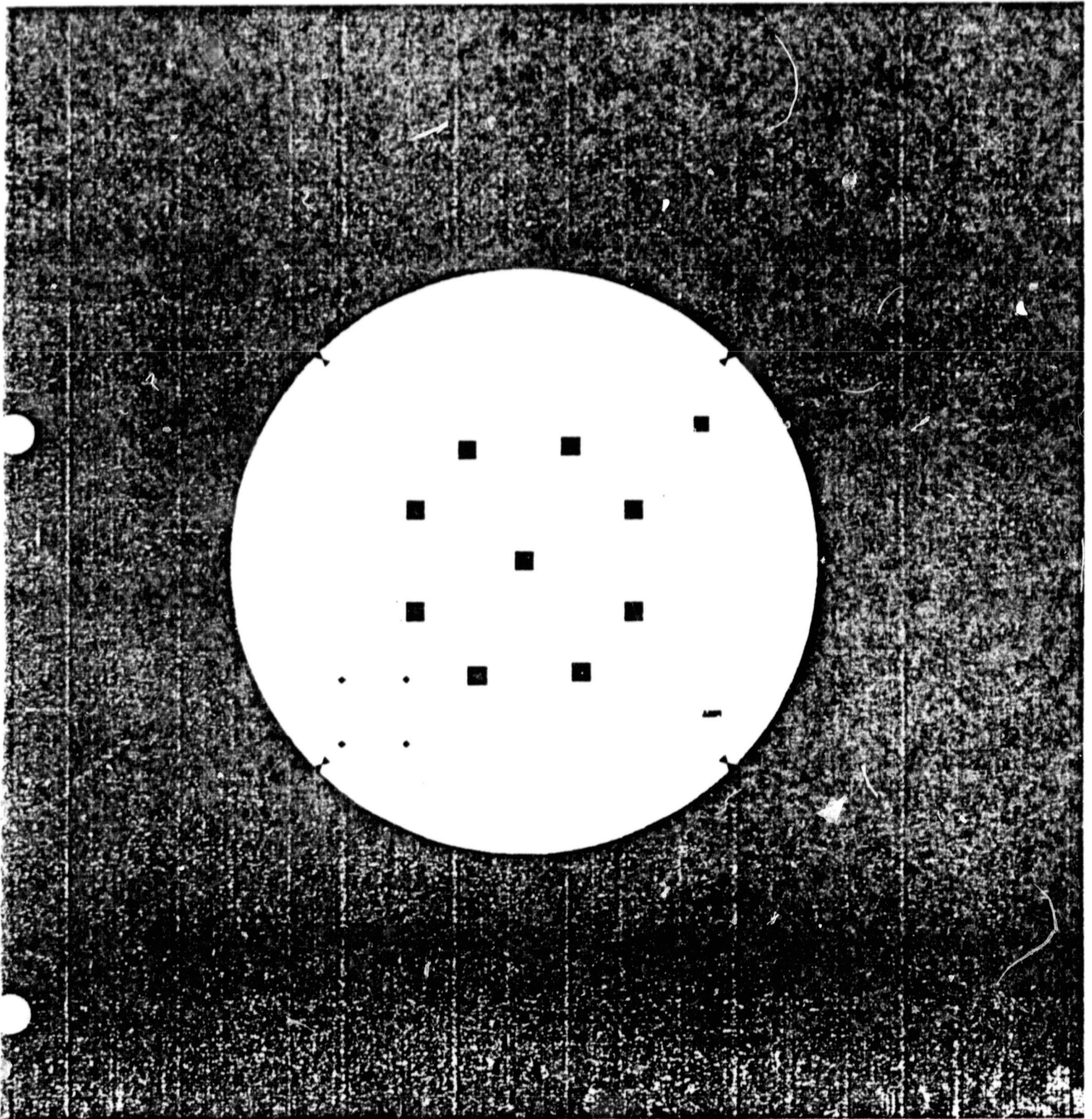
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LAYER 42 - PIEZORESISTOR AND LEADOUT IMPLANT



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LAYER 64 - CONTACT CUT AND TE BOND AREA



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LAYER 70 - METAL INTERCONNECT AND WIRE BOND PADS

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